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Effect of pond type on physicochemical parameters, phytoplankton diversity and primary production in, Kisii, Kenya

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Abstract
The study was conducted to establish the effect of pond type on physicochemical parameters, phytoplankton diversity and primary production in three different types of fish ponds: liner, earthen and concrete at Kegati Kisii, Kenya. The study was conducted from the month of June 2015 to the month of November 2015. Phytoplankton diversity index was calculated by Shannon Wiener index. Statistical significance was set at $p < 0.05$. There was a significant difference in temperature, dissolved oxygen, conductivity, pH and Secchi depth in the three ponds (ANOVA; $p<0.05$). There was no significant difference in nutrients measured in the three types of ponds (ANOVA; $P>0.05$). In liner ponds *Coelomoron mierostoldes* species was dominant while *Anabaena flos-aquae* were dominant in earthen pond while *Microcystis aeruginosa* was dominant in concrete pond. Liner pond had higher Shannon Wiener index 3.418, earthen pond 3.0439 and concrete pond 1.6414.

Keywords: phytoplankton; physicochemical; liner; primary production

1. Introduction

Phytoplanktons are single celled organism of plant origin which exhibit free floating behavior and form colonies that grow photoautotrophically in most aquatic systems. Phytoplankton plays an important part in nutrient recycling and primary production in the Earth by acting as the main producers in any given water environment [1]. Phytoplankton colonizes the surface of the water column, to the depth where light is not able to penetrate. The abundance and structure of the populations of phytoplankton are majorly regulated by inorganic nutrients which include but not limited to nitrogen, phosphorus, and silica. The major available nitrogen occurs as nitrate, nitrite and ammonia. Phosphorus occurs as soluble orthophosphate while silicone exists in form of silicates [2].

An insight on planktonic biomass present in an ecosystem is valuable for fish farming. Despite the fact that phytoplankton is vital for any aquatic ecosystem it should be in range that is optimum to ensure high productivity. Phytoplankton is an important food item of most aquatic organisms and it serves as an indicator for the productivity of water bodies. The community of plankton consists of the primary producers and zooplankton. The phytoplankton represents the biological wealth of a water body, which constitute an important link in the food chain [3]. The abundance of phytoplankton both qualitatively and quantitatively in a pond are pivotal for management of successful pond fish farming activities. Phytoplankton does not only serve as food for aquatic animals, but also plays a pivotal task in maintenance of the water quality and biological balance. They are known to respond quickly to environmental changes and possess a short span of life [4].

A fish pond is an environment created by man which is unique in its own way that requires proper management in order to achieve high productivity. Live water organisms comprise of three main categories namely; phytoplankton, nekton and the benthic organisms. Among the above groups, phytoplankton is important to fisheries and it is vital in influencing pond productivity in terms of fish yields. It is the lowest strophic level in aquatic food chain in all most types of water systems and therefore is utilized as food by aquatic organisms both directly and indirectly. This research was based on the effect of pond type on physicochemical parameters, phytoplankton diversity and primary production in three different types of fish ponds in Kegati aquaculture station. Various ponds have been constructed within the station for fish farming, research and extension. Rearing of fish in ponds started in Kenya in mid-1920's, starting with the keeping of tilapia (*Oreochromis niloticus*) and later the common carp (*Cyprinus carpio*) closely followed by the African catfish (*Clarius gariepinus)* [5]. Currently, fish farming in ponds is being done in the country in both small scale and to a lesser extent in large scale with slight value addition.

2. Materials and Methods

2.1 Studied area

This research was carried out at Kenya Marine and Fisheries Research Institute (KMFRI), Kegati aquaculture research station, Kisii County, Kenya ($00^0$42; $034^0$47E). The station lies at 1700m above sea level with a highland equatorial climate which receives rain almost throughout the year with two major rainy seasons; March to May which is the long rain season and October to November which is the short rainy season. The mean annual rainfall for the area is over 1800 mm. The months of January and July are partially dry. The highest temperatures range between 21 °C to 30 °C while the lowest temperatures range between 15 °C to 20 °C. Kegati region is characterized by a hilly topography with several ridges and valleys. The area comprise of swampy wetland with evergreen deciduous vegetation.

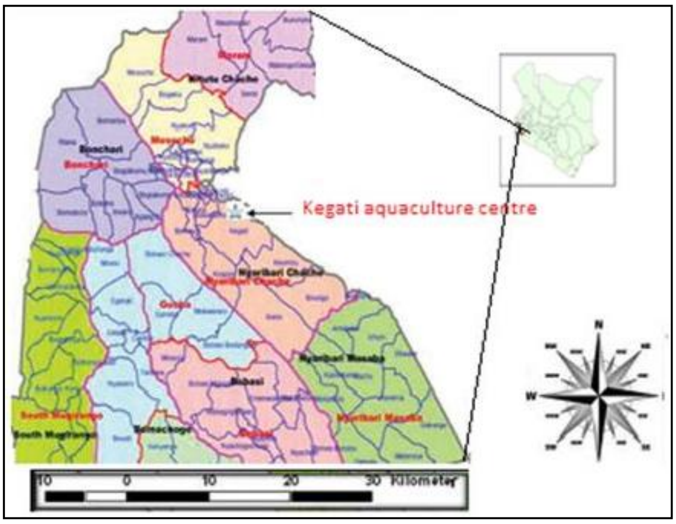

Fig 1: Map of the study area

3. Sampling

3.1 Physico-chemical parameters and Nutrient sampling

For studying physical and chemical parameters of the pond water, monthly sampling was carried out from the month of June 2015 to November 2015. Water samples were collected 10 cm below the surface of the water in the ponds into 100 ml plastic water bottles. Temperature, pH, and conductivity were measured in situ at the middle of each pond at 10cm below the surface. Temperature was recorded by mercury bulb thermometer, pH with digital pH meter model HANNA pH-211. Transparency was measured by lowering the Secchi disc vertically into the pond water until the disc disappeared and the depth recorded, the disc was then raised and the depth at which it reappeared was also recorded. The depth (cm) was the average of the two measurements. Conductivity was measured a conductivity meter model DDS-307 whereby the probe of the meter was immersed at a depth of 10cm from the surface then readings were read from the screen. Dissolved oxygen was calculated by using Winkler method [6]. Soluble reactive phosphorous (SRP), nitrate (NO_3-N), nitrite (NO_2-N), and ammonia (NH_4-N) were measured following the guidelines provided in the American Public Health Association [7]. Total phosphorous (TP) and Total Nitrogen (TN) were calculated using wet combustion method [8].Turbidity was measured by spectrophotometry where hydrazine sulphate and hexamethylenetetramine solutions were mixed and used as the stock solution with 4000 nephelometric turbidity units (NTU) for the calibration in the DR 2000 HACH spectrophotometer. Alkalinity was determined using the methyl orange method [9, 10]. Algal biomass was determined using chlorophyll-*a* method [11]. Photosynthetic rates were calculated using standard methods [12].

3.2 Phytoplankton diversity

Phytoplankton diversity was calculated by Shannon-Winner diversity index as:

$$H' = -\sum P_i Ln\,(P_i) \qquad (1)$$

Where,
H' = the Shannon-Weaver Diversity Index
P_i= the relative abundance of each group of organisms
H'=Shannon-Weaver index

3.3 Photosynthetic rates

Photosynthetic rates were measured monthly using the light-dark bottles technique. Samples were collected using rubber stoppered black and white Biochemical Oxygen Demand (BOD) bottles of 250 ml. The bottles were suspended about 10 cm below the pond water surface. The light and dark bottle was incubated at a depth of 10 cm where the samples were taken for a period of one hour. Concentrations of oxygen in the incubated and the initial bottles were determined using the azide modification of the Winkler method. Photosynthetic rates were calculated using the following formulae.

Photosynthetic rate was calculated by:

i. Net Photosynthesis (NP)

NP=LB-IB $mgO_2l^{-1}hr^{-1}$
Where by
LB= Light bottle
IB= Initial bottle

ii. Gross photosynthesis (GP)

GP = LB – DB $mgO_2l^{-1}hr^{-1}$
Where by
LB= Light bottle
DB= Dark bottle

4. Results and Discussion

In the present results higher temperature was recorded in liner ponds than the earthen and concrete ponds (Table 1). This could be attributed to the fact that liner ponds were made of thick black polythene paper which absorbed more heat from the sun as compared to the other ponds. The fluctuations of pond water temperature could be due to atmospheric variables such as air temperature, wind direction and pond bottom.

Total suspended solids (TSS) could be another probable cause of high temperatures which absorbed heat from the sunlight leading to rise in water temperature and decreased oxygen in the pond [13]. Health condition of selected exotic fishes from farming conditions of Mymensingh area in Bangladesh, found water temperature in earthen ponds ranging from 17 ºC to 31 ºC. [14] Studies on the effects of urea along with a constant supply of quality of poultry manure on phytoplankton production in earthen fish ponds, reveals that pond water temperature varied from 26.3 ºC to 33 ºC [15]. Low amount of dissolved oxygen was recorded in liner pond as compared to concrete and liner ponds which could be due to high mean temperature recorded in the liner pond. This is because dissolved oxygen of water decline with increase in temperature of the water and vice versa. Liner pond recorded the minimum amount of dissolved oxygen probably due to high temperatures. Higher dissolved oxygen levels in earthen and concrete ponds can be attributed to low temperature. A mean of 7.03±0.49 dissolved oxygen has been recorded in studies on physicochemical characteristics and phytoplankton diversity in fish ponds [16]. Yet other studies have shown a dissolved oxygen concentration of 2.53 mgl^{-1} for drainage water and 5.68 mgl^{-1} for irrigation water [17]. The variation in conductivity levels observed in the three types of ponds in this study could be due to pond bottom material on which the ponds were built, but it could be due to the effect of anthropogenic activity. Conductivity values greater than 100 µscm-1 are an indication of human activity [18]. Optimal range of conductivity in fish ponds should be between 100 μscm^{-1} to and 2000 µscm-1. Studies on physicochemical analysis and freshwater fish pond conservation obtained a conductivity range of 296.3±1.73-613.7±3.03 µscm-1[10] which was slightly higher than what was recorded in this study. [19]. A range of conductivity of between 426.43±26.67-1529.08 μscm^{-1} has been found in newly dug earthen fish ponds which were slightly higher than those obtained in this study. The pH mean ranged from 6.2 to 9.0 in all ponds in this study. However other studies on health condition of farmed tilapia and growth, survival and production performance of monosex tilapia, in earthen pond show pH range of between 6.5 and 8.5 [20]. The recorded pH in this study varied slightly over the period of study indicating well buffered conditions in the three types of ponds. The relatively higher pH value in the liner pond as compared to both concrete and earthen pond could be attributed to the increase in carbon dioxide production due to the increased photosynthetic activities of phytoplankton. The present pH results are in agreement with [21, 22, 23, 24]. In the present study liner pond recorded relatively higher turbidity compared to concrete and earthen pond this could be attributed to high phytoplankton densities which was recorded in the liner pond this was confirmed by the higher levels of chlorophyll *a* contents which was recorded during the study period. Higher phytoplankton densities in the water column may lead to increased turbidity [25]. In this study mean turbidity values of 104.2±8.5 NTU were recorded this was higher than a range of between 32.5 and 34 NTU recorded by others while researching on the general distribution and diversity of phytoplankton in earthen freshwater fish ponds [26]. The high turbidity in earthen pond in this study can be attributed to enhanced wind mixing, gentle settling of clay particles and the bare earthen pond dikes which released clay particles more readily into the ponds water. The mean hardness value recorded in the three ponds was 25.0-46.6±4.3, 49.0±3.4, 56.4±3.8 mgl^{-1} in concrete, earthen and liner ponds respectively. However, a mean hardness of 56.0±2.56 mgl^{-1} has been reported in other studies on plankton distribution in earthen ponds. Turbidity range of 48.8-110 mgl^{-1} in earthen ponds similar to that recorded in this study has been reported [27, 28]. This may be associated with the settlement of suspended solids as ponds are less disturbed and the stagnant nature of pond water. The higher hardness level recorded in liner pond compared with concrete and earthen pond could be attributed to higher photosynthetic activity in the liner pond compared to concrete and earthen pond. Higher photosynthetic activities are known to cause the release of carboxyl (OH^-) group in fish ponds which plays an important role in the binding of Calcium (Ca) with the carbonate group (CO_3) to form $CaCO_3$[29]. Fluctuation of hardness of between 183 mgl^{-1} to 440 mgl^{-1} has been observed [30] which was higher than the present study findings. This study recorded lower alkalinity in liner ponds as compared to concrete and earthen ponds. This could be due to high pH value recorded in the liner pond which facilitated photosynthetic rate, resulting to depletion of carbon dioxide. On the other hand, hydrolysis of bicarbonate ions in the pond due to pH may have probably lead to low alkalinity in the liner pond. Autotrophic activities in fish ponds increases pH through CO_2 absorption, while heterotrophic activities in fish ponds decreases pH through respiration, as autotrophic and heterotrophic processes in fish ponds affect the measured parameter in an opposite manner[31]. Secchi depth was lower in liner pond than concrete pond and earthen pond which could be attributed to higher primary productivity in the liner pond. The relatively higher secchi depth measurement recorded in concrete pond could probably due to low phytoplankton growth in the pond [32]. The ranges of secchi depth measurement obtained in this study are similar with others studying phytoplankton productivity in newly dug fish ponds [33, 34]. The amount of total dissolved solids (TDS) recorded in this study in concrete and liner ponds were similar to related studies. Moreover, a TDS range of 140-230 mgl^{-1} was obtained in research on phytoplankton diversity and its relationship to physicochemical parameters [35]. Further, results from physicochemical analysis and pond conservation recorded total suspended solids range of 20.5±2.35-100.6±4.98 mgl^{-1}. Physicochemical parameters from artificial concrete ponds recorded total suspended solids of 75.97-96.9 mgl^{-1}. In the present study, a higher total suspended solid was recorded in liner pond this could be attributed to higher turbidity which was recorded in the pond. Liner pond recorded higher level of total dissolved salts as compared with concrete and liner pond. This could be attributed to higher electrical conductivity recorded in the pond. Total dissolved solids value in mgl^{-1} is about half of the electrical conductivity (μScm^{-1}). On the other hand electrical conductivity is related to salt content, hence an increased level of conductivity in liner pond is related to an increased salt content, and hence an increase in conductivity of the water which indicates an addition of mineral salts to the water. Total nitrogen concentration ranged from 272.81 μgl^{-1}in liner ponds to 2887.6 μgl^{-1} in concrete ponds with a mean of 728.2±68.1 μgl^{-1} in this study which was similar with studies on plankton distribution and diversity in earthen ponds which recorded nitrate range of 200 - 300 μgl^{-1}[36]. The high amounts of nitrates in earthen pond could be due to nitrogen rich run-off into the ponds. Concrete pond recorded relatively high amount of total nitrogen due to low number of nitrifying bacteria and the absence of soil medium in the bottom of the pond [37].

The mean total phosphorous levels were 458.7±50.8 in liner ponds in this study (Table 2). This was lower than 610-1010 μg l^{-1} from studies on phytoplankton diversity and its relationship to physicochemical parameters. Earthen pond recorded a higher amount of ammonia level as compared with concrete and liner pond, this could be attributed to effects of pH in the pond since pH had a positive correlation with ammonia level in the earthen pond. Formation of ammonia depends on pH and there is a positive relationship between increasing pH and release of free toxic ammonia from the total ammonia nitrogen. Ammonia-nitrogen is found to have had a toxic nature at high pH level and less toxic at low pH [38]. Concrete pond recorded comparatively high amount of total nitrite due to low number of nitrifying bacteria and because of the absence of soil medium at the bottom of the pond. In the current study, earthen pond recorded higher level of nitrate as compared to concrete and liner pond. This could be attributed to the high level of ammonia in the earthen pond which probably got nitrified to nitrate in the presence of dissolved oxygen.

The higher values of Shannon's index (H) in liner ponds of 3.417 indicated greater species diversity as compared to earthen ponds 3.04 and concrete pond 1.641 (Table 3). This difference may be due to the fact that the liner ponds and concrete ponds had no outlet and therefore could not loose fertility in the water flowing out of the ponds as compared to earthen pond physicochemical parameters. In addition, high Shannon index in liner pond could be attributed suitable ecological conditions of the liner pond. Differences in phytoplankton diversity could also be an indication that phytoplankton diversity is affected by the pond type and physicochemical parameters. The amount of gross primary production was found to be higher than the amount of net primary production (Table 4). This could be due to the fact that, from the three types of ponds phytoplankton cells lost significant levels of assimilated carbon during various metabolic processes in particular via excretion and respiration. Higher amount of net primary production in liner pond could be due to favorable conditions in the pond [39]. The variation in the rates of production in the three types of ponds could be due to favorable or unfavorable physicochemical conditions exhibited by the three types of ponds during the study period.

Table 1: Mean (±SE) of physicochemical parameters in concrete, earthen and liner ponds at Kegati between June 2015 and November 2015

Parameter	Concrete pond	Earthen pond	Liner pond
Temperature (°C)	24.2±0.4	24.1±0.4	26.0±0.4
Dissolved Oxygen (mgl^{-1})	7.0±0.2	6.7±0.2	6.0±0.3
Conductivity (μScm^{-1})	86.8±4.0	106.3±7.9	114.2±7.3
pH	7.4±0.1	7.4±0.1	7.8±0.1
Turbidity (mgl^{-1})	95.8±5.8	104.2±8.5	107.6±10.6
Hardness (mgl^{-1})	46.6±4.3	49.0±3.4	56.4±3.8
Alkalinity (mgl^{-1})	73.9±4.1	70.2±2.2	64.5±4.1
Secchi disk (cm)	14.5±0.8	13.1±0.6	12.7±2.2
Total suspended solids (mgl^{-1})	52.3±41.8	59.2±12.0	63.6±6.9
Total dissolved solids (mgl^{-1})	45.9±9.0	50.2±8.1	58.8±8.6

Table 2: Nutrient levels in concrete, earthen and liner, fish ponds at Kegati between June 2015 and November 2015

Parameter	Concrete pond	Earthen pond	Liner pond
Total nitrogen (µgl-1)	870.5±127.9	919.6±175.8	728.2±68.1
Total phosphorus (µgl-1)	340.4±80.8	527.8±146.5	458.7±50.8
Ammonia NH4+ (µgl-1)	245.5±60.5	249.1±70.6	237.8±81.1
Nitrites NO2- (µgl-1)	42.3±10.6	49.5±16.5	22.4±4.9
Nitrates NO3- (µgl-1)	106.4±25.6	153.3±36.5	102.4±20.4

Table 3: Phytoplankton diversity indices in liner pond, earthen pond and concrete pond between June 2015 to November 2015

Diversity indices	Concrete pond	Earthen pond	Liner pond
Shannon Wiener index	1.6414	3.0439	3.4179

Table 4: Primary production and net primary production in concrete, earthen and liner between June 2015 and November 2015

Parameter	Concrete pond	Earthen pond	Liner pond
Gross primary production GPP in $mgO_2l^{-1}hr^{-1}$	0.43	0.85	0.98
Net primary production NPP in $mgO_2l^{-1}hr^{-1}$	0.33	0.52	0.65

5. Conclusion

From results obtained in this study it can be concluded that the abundance and composition of phytoplankton was affected by the pond type and physicochemical condition of the pond. A high abundance and species composition of phytoplankton was found in lined pond as compared to earthen and concrete fish ponds. Although phytoplankton exists under a wide range of environmental conditions many species in the present study were limited by amount of dissolved oxygen, temperature and pond type. Liner pond had higher levels of both chlorophyll a and amounts of both gross and net primary production as compared to measurements recorded from earthen and concrete ponds.

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